International Journal of Scientific & Engineering Research Volume 10, Issue 5, May-2019
ISSN 2229-5518

Acoustical Retrofitting of Auditoriums: A Case Study of a Multipurpose Auditorium with Proposals to Improve its Performance.

Abhirami P A, Ajin Krishna K B, Anagha K S, Athira Dinesh C, Jayadevan V

Abstract--: This paper looks into the possibilities of improving the acoustical performance of Pranavam auditorium, Vidya academy campus Thrissur based on a detailed study of the sound decay at various locations of the auditorium using a standard sound level meter and the associated software. The study brings out a couple of cost effective proposals, based on a thorough market study, to improve the overall acoustical quality of the auditorium.

Index Terms—: Pink sound, Pure Tone, RT_{60}, Acoustic baffles, NRC value, Sound decay, dBA

1 INTRODUCTION

Designing an acoustically well behaved working space is an involved task. It becomes trickier in case of large auditoriums. The Pranavam auditorium of Vidya Academy of Science and Technology, Thrissur is a large multipurpose auditorium with reasonably good acoustical characteristics. However it is felt that there is an issue of lack of speech clarity in the auditorium especially when the number of audience is less. In this work, a thorough analysis of the sound decay in the hall is carried out using a sound meter (HTC: SL-1352) having a data logging facility. Studies are conducted using pink sound as well as pure tones of frequencies 250, 500, 1000 and 2000 Hz. The existing reverberation is found to be more than a second high for one-third occupancy of the audience. Two cost effective options are proposed with fixed and variable additional absorption features to bring the reverberation down to the desirable value.

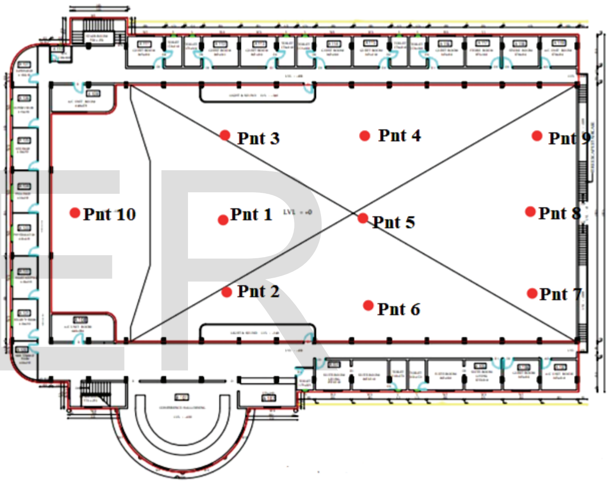

Figure 1: Measurement positions

2 APPROACH

The reverberation time, RT60 is given by the Sabine's formula RT60= 0.16*V/A. 'V' is the volume of the hall in cubic meters and 'A' is the total absorption available in the hall in 'meter square Sabine'. As, it is impossible to precisely determine the acoustical characteristics of different surfaces used inside the auditorium, an indirect approach is used to find the total existing absorption. Nine points inside the auditorium and a point at the centre of the stage were selected for observing the sound decay (Fig.1). The background noise level inside the auditorium was 35-40 dBA. To measure RT60 directly, it was required to generate a sound level above 100 dBA which was not easy and hence it was decided to measure RT30 and calculate RT60 from RT30 value.

Knowing the value of RT60, using Sabine's formula, the total effective absorption in the auditorium is found. Based on the optimum reverberation required for such a hall as per fig.2, the total absorption required is found. The difference in these values minus the absorption due to the audience will be the additional absorption to be provided.

3 STUDY CONDUCTED USING PINK SOUND

Pink sound is acoustical energy distributed uniformly by octave throughout the audio spectrum (the range of human hearing, approximately 20 Hz to 20 kHz). Pink sound is having uniform spectral power density and the same apparent loudness at all frequencies. In pink sound, the total sound power in each octave is the same as the total sound power in the octave immediately above or below it.

Using Pink Sound as source, reverberation times were measured in 10 different positions mentioned above and indicated in fig-1. RT30 was measured as the time required for the decrease of loudness from 80 dBA to 50 dBA.

Twice this value will be the reverberation time or RT_{60}. The observed reverberation time in seconds using pink sound is

Abhirami P A, Ajin Krishna K B, Anagha K S, Athira Dinesh C, Final year B.tech Students, Department of Civil Engineering, Vidya Academy of Science and Technology, Thrissur

Jayadevan V, Visiting Professor, Department of Civil Engineering, Vidya Academy of Science and Technology, Thrissur, vjdcricket@gmail.com

furnished in table-1.

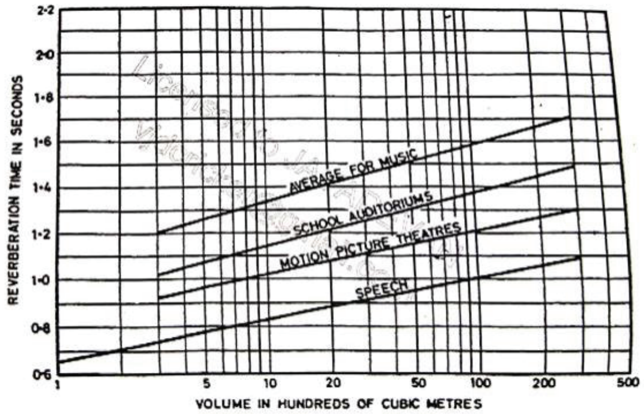

Fig.2: IS: 2526 Chart for determining optimum reverberation time for different acoustical spaces

Point	RT_{60}
P1	3.2
P2	2.92
P3	3.20
P4	3.20
P5	2.80
P6	3.20
P7	3.20
P9	2.80
P10	3.20
Average	3.05

Table-1: Measured reverberation time using Pink sound

Average Reverberation Obtained from Pink Sound Measurement = 3.05 seconds. Though pink sound is a good sound source to qualitatively assess the performance of an acoustically important space, for a more precise determination of the total absorption NRC (Noise reduction coefficient) value based approach is preferred. NRC value is the average sound absorption coefficient of a surface for four different frequencies 250 Hz., 500 Hz., 1000 Hz. and 2000 Hz.

4 Study Conducted Using Frequencies 250 Hz. 500 Hz., 1000 Hz. and 2000Hz.

Using Pure Tone of frequencies 250Hz, 500Hz, 1000Hz, and 2000Hz, reverberation times were measured at different points shown in Fig.1. The Reverberation time for each frequency tone at each point is given in table-2.

Location	RT60 Using 250Hz (Sec.)	RT60 Using 500Hz (Sec.)	RT60 Using 1000Hz (Sec.)	RT60 Using 2000Hz (Sec.)	Average RT60 (Sec.)
P1	2.52	2.52	2.52	2.52	2.52
P2	2.56	2.56	2.52	2.44	2.52
P3	2.64	2.64	2.52	2.52	2.58
P4	2.64	2.6	2.52	2.52	2.57
P5	2.44	2.44	2.4	2.32	2.4
P6	2.48	2.32	2.32	2.32	2.36
P7	2.48	2.48	2.4	2.4	2.44
P8	2.52	2.52	2.48	2.48	2.5
P9	2.48	2.48	2.48	2.4	2.46
P10	2.4	2.4	2.32	2.32	2.36

Table-2: Reverberation time for different frequencies

Total average Reverberation time of the entire auditorium = 2.47 seconds

A sample curve showing the sound decay is given in fig.3

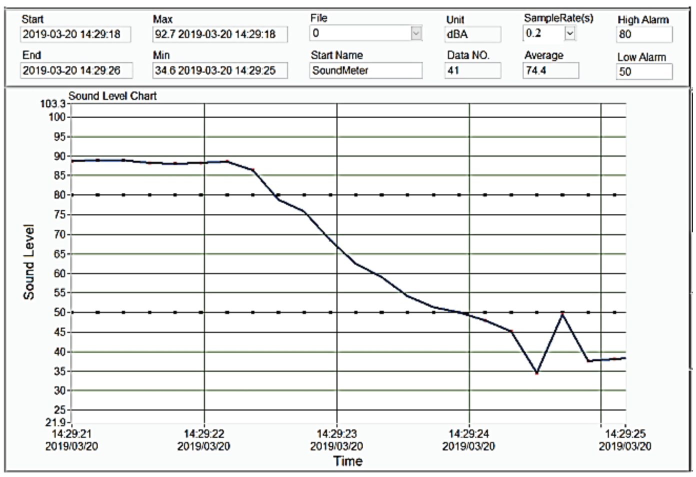

Fig.3: A typical sound decay curve (for pure tone, 500 Hz.)

5 Analysis

As per Figure-2, the Reverberation time of this auditorium should be 1.3 seconds only. So, to bring down the Reverberation time from 2.47 to 1.3 seconds, additional absorption materials should be added in the interior. To find the value of supplementary absorption needed, the existing absorption including the absorption of audience should be calculated.

Average reverberation time in the hall = 2.47 s

Volume of the auditorium = 8019.675 m^3

As per Sabine's equation, existing absorption (A1) without considering the absorption of the audience is equal to (0.16*8019.675)/2.47 = 520 Metric Sabine

Total capacity of the auditorium = Floor area /0.9 = 995/0.9 = 1100 Person

Number of people occupied when occupied at two third of the capacity = 730

Number of people occupied when occupied at one third of the capacity = 365

Absorption of one person occupied in an ordinary chair without cushion may be taken approximately as 0.36 Metric Sabine (with cushioned seats it is 0.46)

The average absorption value of the auditorium with one third, two third and full capacity of the audience is shown in Table-3.

Situation	One Third of the capacity Occupied	Two Thirds of the capacity is Occupied	Occupied to the full capacity
Absorption by the Audience in Metric Sabine (A2)	132	263	396
Total Absorption in Metric Sabine (A1+A2)	652	783	916

Table-3: Total absorption with varying presence of audience

As per Sabine's Equation the required absorption (A3)= (0.16*8019.675)/1.3= 988 Metric Sabine

From these calculations, it is clear that, the auditorium should be working satisfactorily, when it is occupied to the full capacity even without any further acoustical treatment. But this situation occurs very rarely and it will be more sensible to treat the auditorium with variable absorption features to cater the needs of 2/3rd and 1/3rd capacities.

The additional absorption needed with 2/3rd capacity = 988-783 = 205 m^2 Sabine

The additional absorption needed with 1/3rd capacity = 988-652 = 336 m^2 Sabine

For providing this additional absorption, different methods of retrofitting can be adopted.

6 Proposed Retrofitting Options

Two type of rectification method could be adopted for achieving the additional sound absorption. Two proposed methods are:
Providing Baffle absorbers on Ceiling

Providing a dividing Curtain to make use of during low occupancy situations

6.1 Mandatory requirements for both the options

An area about 43.2 m^2 freely available at the rear wall can be treated with sound absorbing materials. Polyester fibre wadding covered with perforated gypsum board is proposed which will give an approximate NRC value of 0.80 Sabine. By this absorption of 35 Metric Sabine can be achieved.

Presently the rear half of the floor of the auditorium is given a slope of around 80 for the people occupying this area to get a better vision. Normally this area will be unoccupied when the auditorium is functioning at 2/3rd or 1/3rd capacity and only a small area of the slope is covered with a carpet.

The entire area may be treated with carpet for getting more absorption. An area including 10 cm raised steps of 350 m^2 could be covered with carpet (NRC value 0.45). Absorption of 158 Metric Sabine can be achieved by doing so.

After these common treatments, only 143 Metric Sabine of sound absorption have to be provided considering one third of the capacity occupied.

6.2 Option-1: Providing acoustic baffles on ceiling

Acoustic baffles are free hanging sound absorption products that are often used to acoustically treat large rooms such as auditoriums. By hanging from the ceiling, baffles reside in space where sound tends to get stuck. They absorb direct sound and, if placed correctly, absorb sound that has bounced off other surfaces such as walls, floors etc. This absorption greatly reduces reverberation time and echo within rooms, which increases speech intelligibility and communication in general. Generally acoustic baffles are uses when wall space is limited or when the room is very large. Just like wall panels, they absorb both direct and reverberant sound. The difference, however, is that all sides of a baffle are exposed and able to absorb sound as shown in the Figure-4. The increased surface area is one of the main reasons why baffles are used in large spaces. In case of Pranavam auditorium the additional absorption needed when one third of capacity occupied is 143 Metric Sabine.

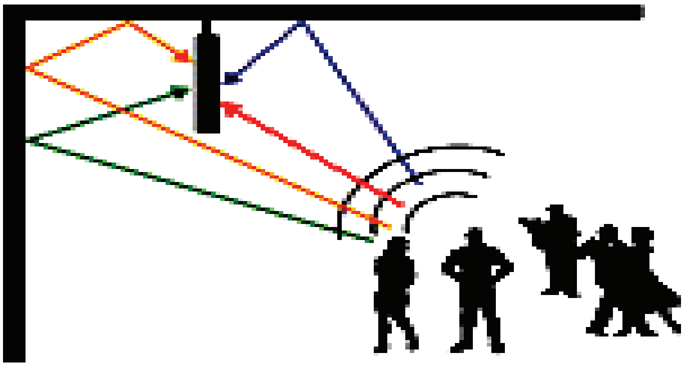

Figure 4: Schematic Diagram of Working of Acoustical Baffled Walls

Polyester fibre panels are perhaps the most economical materials that can be used as baffles.

Panels of size 2.4m x 1.2m x 9mm of absorption value 0.8 per square meter are available in the market at a reasonable cost and can be used as baffles. Considering the both sides absorb sound, a total 1.5 times of 2.4 x 1.2 x 0.8, i.e. 3.45 Metric Sabine will be available per one panel.

By providing 42 baffle panels we can provide absorption of 145 Metric Sabine.
Acoustic baffles can be provided in Pranavam Auditorium as shown in figure-5.

The reverberation time after treatment:
Total absorption value after treatment= 652+35+158+145 = 963 Metric Sabine
RT_{60}= (0.16*8019.675)/963= 1.33 seconds, which is close to the preferred value of 1.3 seconds.

Figure 5: Acoustic baffles

6.3 Option-2: Providing a mid-way curtain to separate the space into two

This method also can be adopted when one third of the capacity of audience only is occupied. A curtain made of thick textile can be used to separate the entire volume of the hall into two parts. When the portion of the hall with slope (plus some part of the flat portion) the volume available on both sides will be 4010m^3 each, i.e. 50% of the entire volume.

Here we assume that in the present situation, the reverberation time in both the spaces is 2.47 seconds itself. Hence the absorption value available for both portions will be 50% of the existing total absorption i.e. 520/2= 260 metric Sabine.

The area of the curtain to be provided is 194 m^2 and NRC value of the curtain may be taken as 0.60 Sabine.

Adding the absorption of 1/3rd audience and that of the curtain, the total absorption after treatment will be, 260+132+194*0.6 = 508 metric Sabine

Reverberation time after providing curtain will be:
RT_{60}= (0.16*4010)/(260 + 132 +194*0.6) = 1.26 seconds which will be ideal for the space of reduced volume.

The way of providing curtain is shown in Fig.6

Figure 6: Providing curtains

7 Conclusion

It is a great experience to attend a program, whether music or speech, in an acoustically well designed space. Even when the space is designed based on thorough acoustical principles, fine tuning based on actual measurements will be mandatory to get the expected sound quality. This is particularly true in cases for big halls and auditoriums. A couple of cost effective alternative proposals are brought out in this paper based on a thorough study of sound decay at various locations inside the hall to improve the acoustical quality of the Pranavam auditorium. It is expected that implementing these designs will significantly improve the overall acoustical quality of this muti purpose auditorium.

8 References

[1] Knudsen V.O and Harris C.M, Acoustical design in Architecture, John Willy, 1980
[2] M David Egan, Architectural Acoustics, J. Ross Publishing 2007
[3] BIS standards: IS-2526-1963
[4] M Barron, Acoustical design of Buildings, on 1983.